ABSTRACT

Liquefaction is a phenomenon in which soil loses a large percentage of its shear resistance due to increased pore water pressure and flows like a liquid. Undrained cyclic loading conditions during earthquakes cause liquefaction of soils, which can lead to catastrophic failures such as bearing capacity failures, slope failures and lateral spreads. The concepts and mechanisms of liquefaction were studied extensively by many researchers. Though the factors affecting the liquefaction response of soils during earthquakes are well documented in literature, there are still some gray areas in understanding the individual and combined effects of factors like frequency, gradation, fines content and surcharge pressure on the initiation of liquefaction. The objective of this thesis is to study the influence of ground motion, soil and site parameters on the initiation of liquefaction in saturated sand beds through laboratory shaking table model tests and numerical studies.

Shaking table tests are carried out using a uniaxial shaking table on sand beds of 600 mm thickness. The initiation of liquefaction was observed and identified by measuring the pore water pressure developed during the sinusoidal cyclic loading. Free field liquefaction studies are carried out on sand beds to study the influence of ground motion parameters, namely, input acceleration and frequency of shaking on liquefaction. These studies revealed that acceleration is one of the important parameters that can affect the initiation of liquefaction in sands. Increase in acceleration reduces the liquefaction resistance of sand and a small increase in acceleration can trigger liquefaction. Frequency of shaking did not affect the initiation of liquefaction at lower frequencies but a threshold frequency which triggered instant increase in the excess pore pressures is observed. Liquefaction caused slight initial amplification followed by de-amplification of accelerations due to the stiffness reduction in soils during liquefaction, the effect being more pronounced in the top layers of the sand bed. Pore water pressure ratios during dynamic loading decreased with depth below the surface of the sand bed due to the low initial effective vertical stress and upward transmission of pore pressure during undrained loading.

Shaking table tests are carried out to study the influence of soil parameters such as relative density, thickness of dry overlying sand layer and gradation. Relative density of sand can influence the liquefaction potential of sand to a great extent, about 10% increase in relative density bringing down the probability of liquefaction by about 50%. With the increase in height of dry overlying sand layer, liquefaction potential has decreased nonlinearly. Change in grain size altered the pattern of liquefaction and pore pressure development and it is observed that the liquefaction in finer sands is influenced by the frequency of shaking to a larger extent. Surcharge pressure from building loads increased the liquefaction potential and heavier structures got liquefied at lower pore water pressure ratios. Significant post-liquefaction de-amplification was observed in sand beds with surcharge pressure.

Parametric numerical analyses are carried out using finite difference program FLAC (Fast Lagrangian Analysis of Continua) with FINN model to measure pore water pressures in the sand bed. Results from numerical analyses with change in the acceleration, surcharge pressure and thickness of dry overlying layer agreed well with the experimental results. However, effect of frequency in numerical studies did not match with the experimental observations, because of the inherent boundary effects in the experimental models. Results from this thesis provided important insights into the development of pore water pressures in sand beds during cyclic loading events, apart from enhancing the understanding towards the effect of various ground motion, site and soil parameters on the initiation of liquefaction in sand beds.